# The Application of Remote Sensing and Machine Learning to Improve Early Warning Systems for Harmful Algal Events in the Highland Lake Chains, TX

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RESEARCH OBJECTIVES

- Use Earth observation data to improve algal bloom monitoring systems

- Create user-friendly tools to monitor near real-time remotely sensed algae and environmental indicators to help our partners determine when and where harmful algal events are likely to occur.

- Detect historical hotspots to help inform future field sampling efforts.
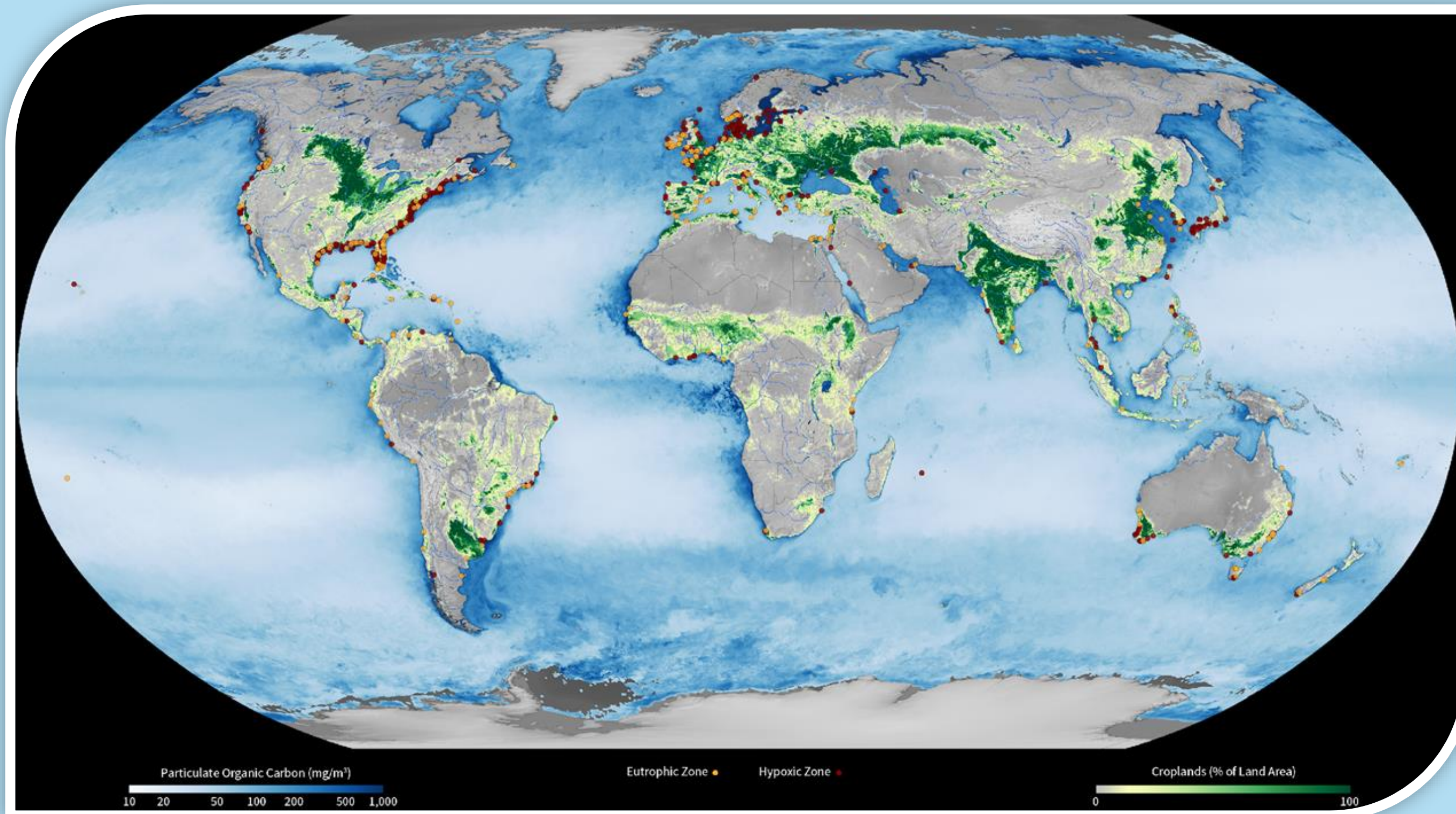
Anthropogenic Eutrophic and Hypoxic Zones : Yellow circles on this map show the location of observed eutrophic zones. Red dots show where hypoxic zones have been observed. Fertilizer-laden runoff triggers explosive planktonic algae growth in coastal areas. Source: NASA
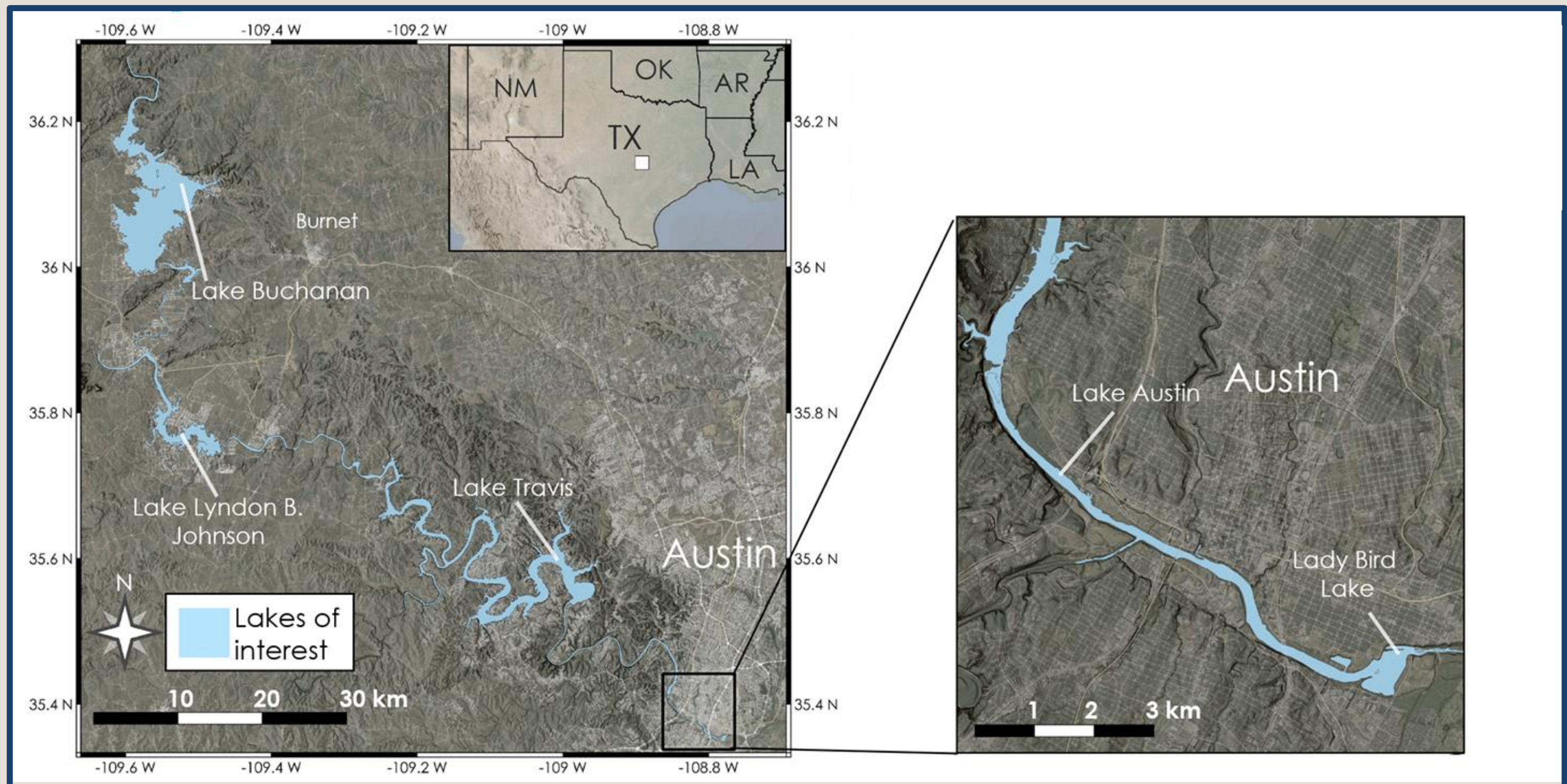
BACKGROUND

The increasing frequency and extent of the development of algal blooms in the many thousands of human-constructed water reservoirs is of particular concern not only from the perspective of aquatic habitat but also due to the frequent use of these reservoirs as both drinking water sources and recreational spaces. Beginning in 2019, harmful algal events have caused canine deaths in both Lady Bird Lake and Lake Travis located near Austin, Texas. These two reservoirs are part of the larger Highland Lakes chain, managed by the City of Austin Department of Watershed Protection (COA DWP) and the Lower Colorado River Authority (LCRA), which fulfill municipal, commercial, and agricultural water demands. The LCRA and the COA DWP have been collecting in situ water samples and routinely monitoring lake conditions for decades. But limitations such as cost and lab delays result in insufficient monitoring coverage from field sampling alone. Given the recent increase in favorable environmental conditions for algal events in Central Texas, our NASA DEVELOP team partnered with the LCRA and COA DWP to improve their monitoring and detection of algal events, through the application of NASA Earth observations and machine learning.

One Health Harmful Algal Bloom System (OHHABS), US, 2019

Most of the 242 HAB events occurred in fresh water (n=181)

25% Salt water
75% Fresh water
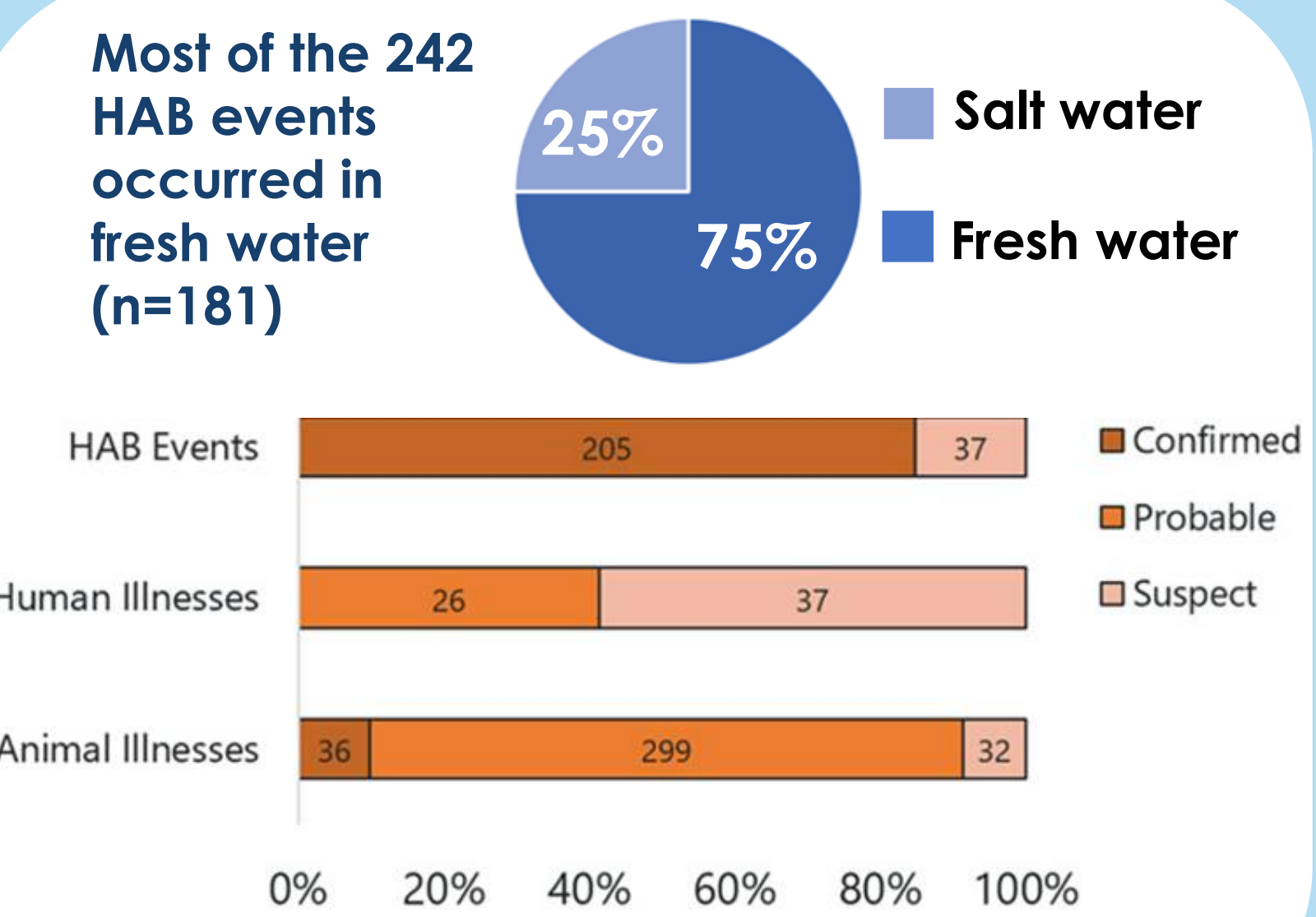
Algae in the Highland Lakes
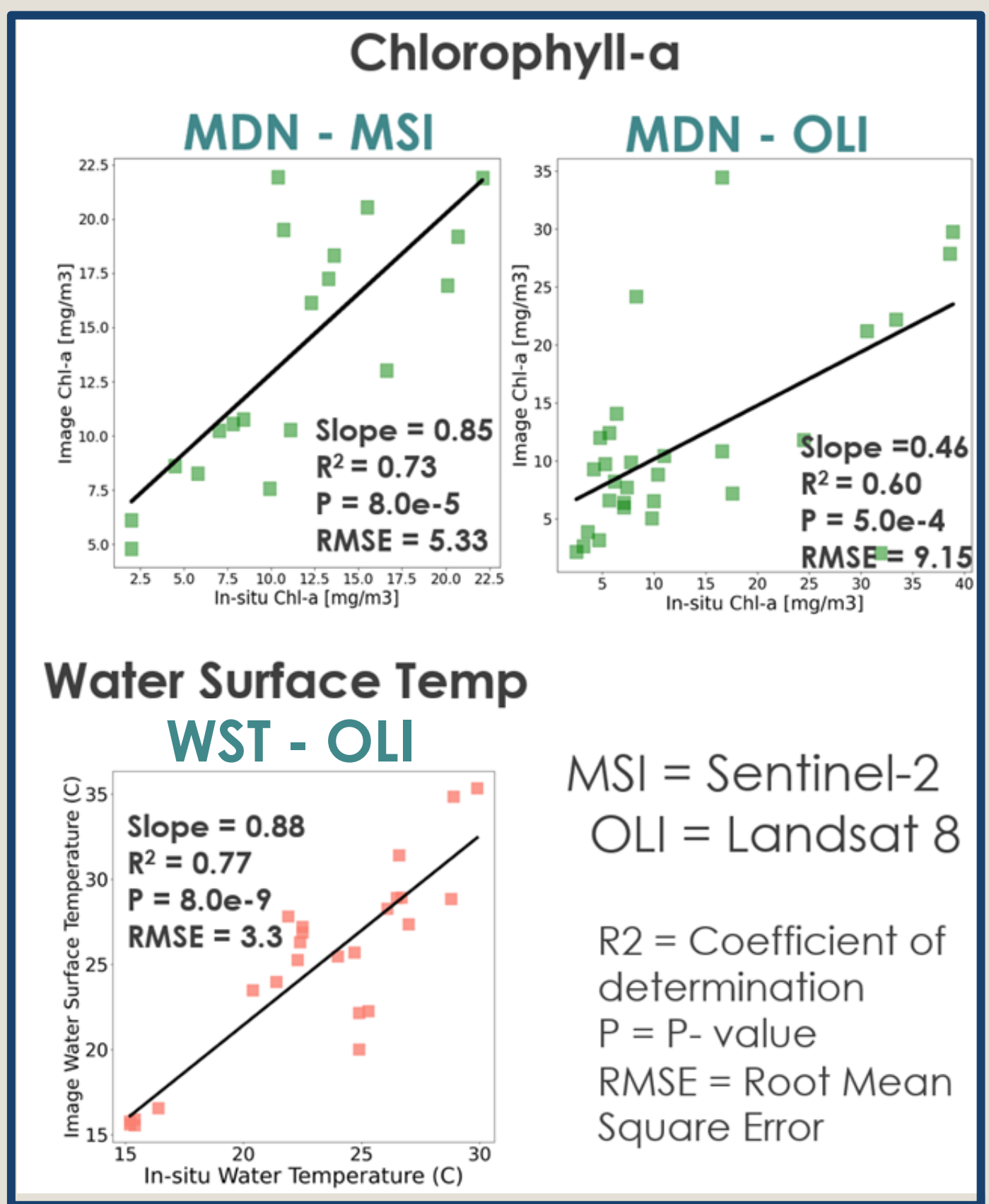Source: LCRA and COA DWP

STUDY AREA

Spatial extent of the study area including all seven reservoirs in the Highland Lakes chain in Central TX, with an inset on the city of Austin and its surrounding reservoirs

Recommended Human Health Recreational Ambient Water Quality Criteria for Microcystins (May 2019)

Risk level	Cyanobacteria (cells/count)	Chlorophyll-a (ug/L)	Microcystin (ug/L)
Low	$\leq 20{,}000$	≤ 10	< 10
Moderate	$> 20{,}000 - 100{,}000$	$> 10 - 50$	$2 - 4\ to\ 20$
High	$> 100{,}000$	> 50	> 20

METHODS

Mixture Density Network Chlorophyll-a
Smith et al. (2021), Pahlevan et al. (2020)

$$\Phi_i\ (Chla|R_{rs}) = \frac{\exp\left(-(1/2)(Chla - \mu_i)^T \sum_i^{-1}(Chla - \mu_i)\right)}{\sqrt{(2\pi)^d|\Sigma_i|}}$$

Broad Wavelength Algae Index (BWAI)
Zhao et al., 2020

Water Surface Temperature
Sekertekin & Bonafoni, 2020

Normalized Difference Turbidity Index (NDTI)
Lacaux et al., 2007

Landsat 8 Launch	Sentinel-2A Launch	Sentinel-2B Launch	Toxins first detected, Lady Bird Lake	Toxins first detected, Lake Travis
2013	2015	2017	2019	2021

Landsat 8 OLI — 16-day revisit
Sentinel-2 MSI (ESA) — 5-day revisit (A + B)

VALIDATIONS

Chlorophyll-a

MDN - MSI
Slope = 0.85
R² = 0.73
P = 8.0e-5
RMSE = 5.33

MDN - OLI
Slope = 0.46
R² = 0.60
P = 5.0e-4
RMSE = 9.15

Water Surface Temp
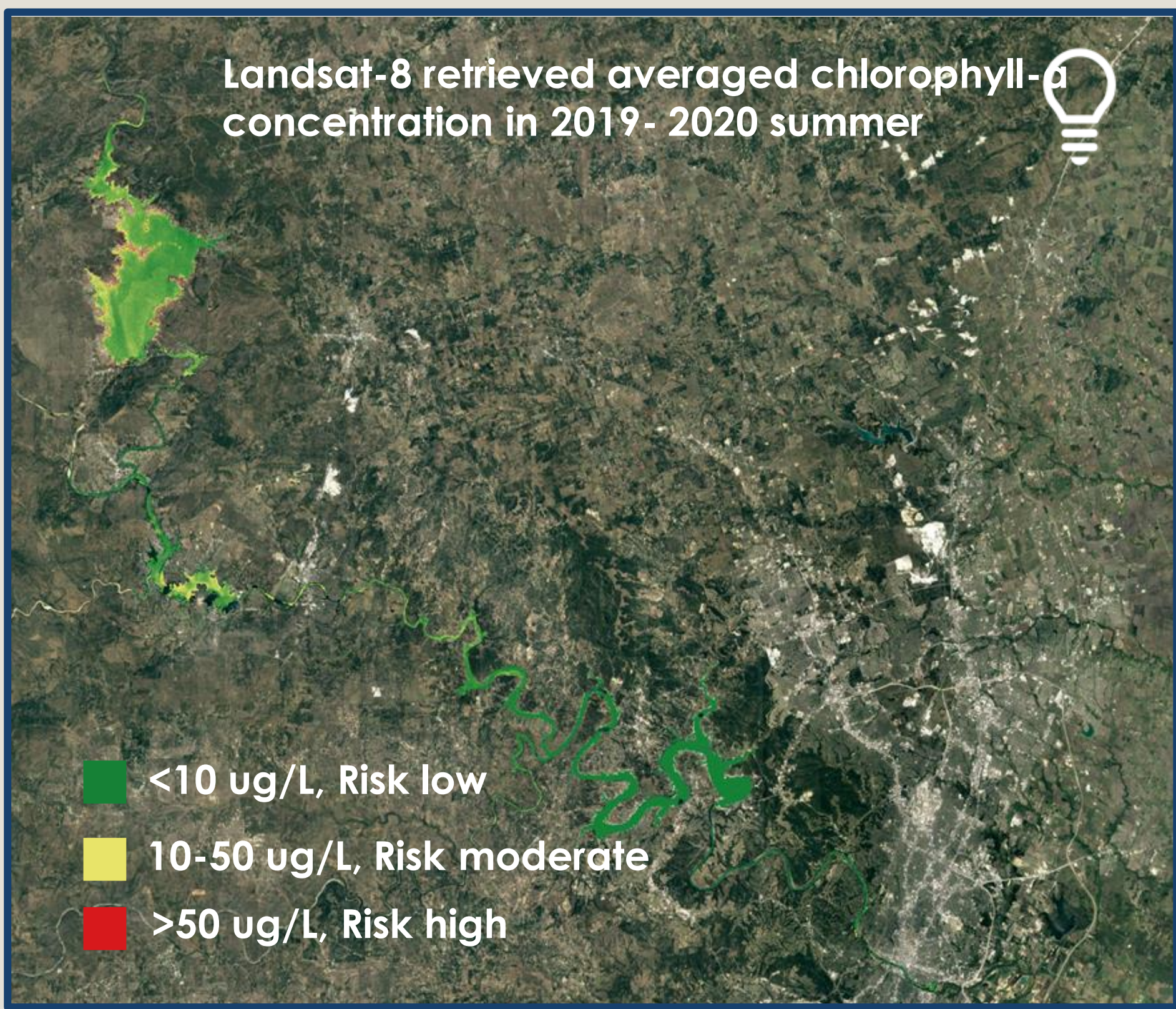**WST - OLI**
Slope = 0.88
R² = 0.77
P = 8.0e-9
RMSE = 3.3

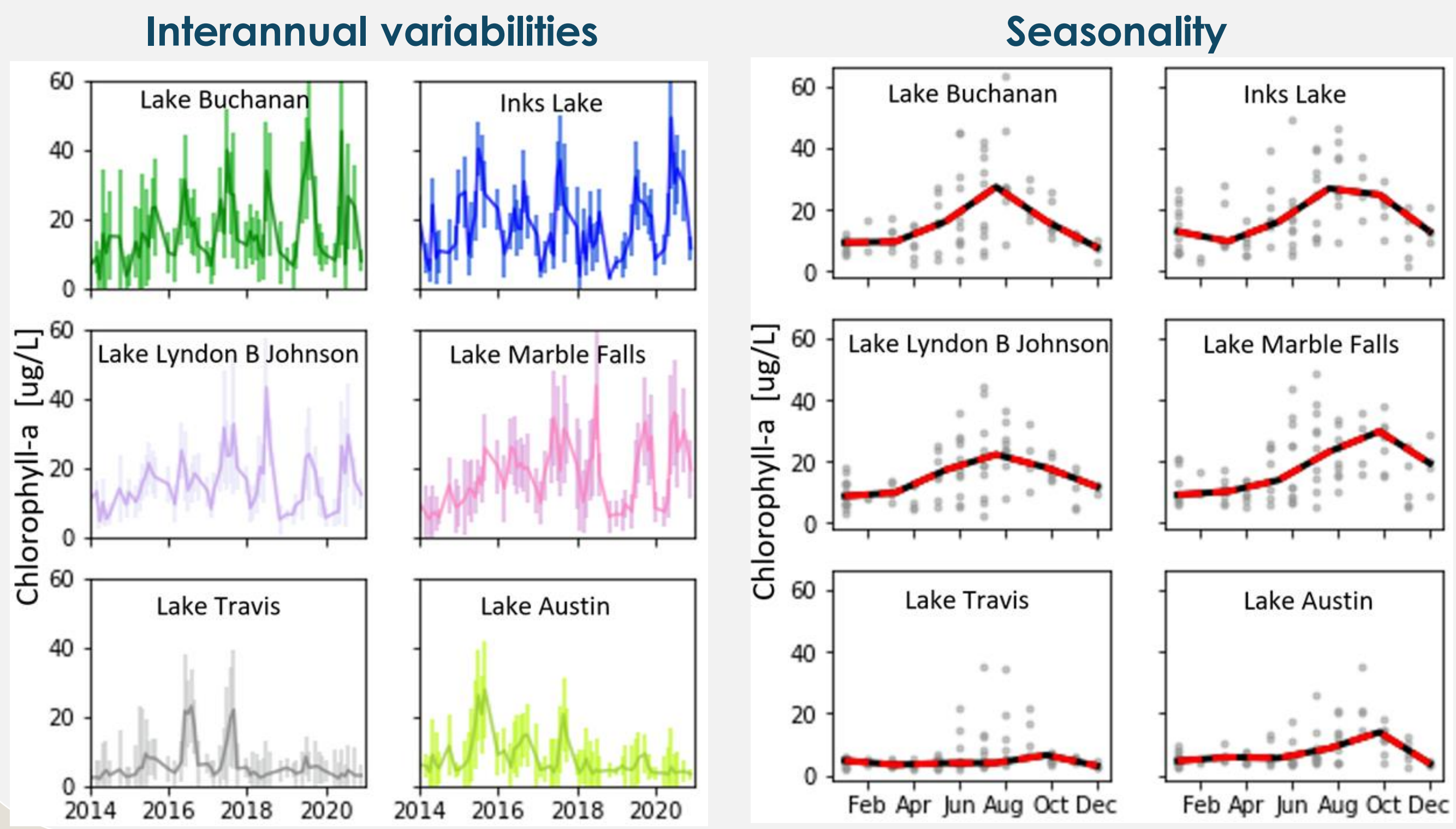MSI = Sentinel-2
OLI = Landsat 8

R2 = Coefficient of determination
P = P- value
RMSE = Root Mean Square Error

ALGAL BLOOM HOTSPOT DETECTIONS

Landsat-8 retrieved averaged chlorophyll-a concentration in 2019 - 2020 summer

<10 ug/L, Risk low
10-50 ug/L, Risk moderate
>50 ug/L, Risk high

HISTORICAL ALGAL BLOOM HOTSPOT DETECTIONS

Interannual variabilities

Seasonality

TOOL/GUI DEVELOPMENT

LAMDA Lake Algal Monitoring Dashboard

Start — Date Slider — End
Info widget
Environmental Proxies Selection
Visualization
Data downloading
Time-series stats
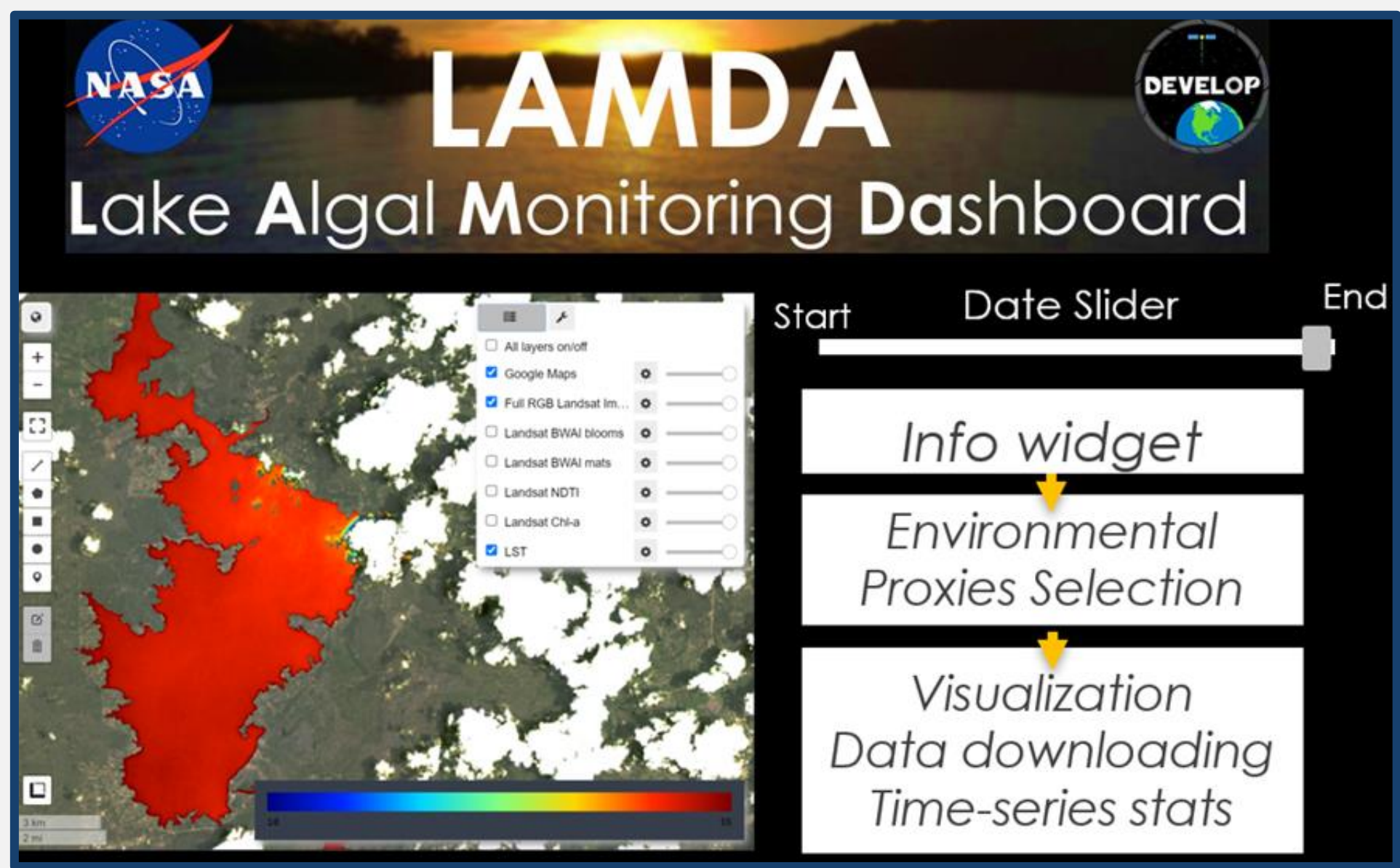
The resulting products enable near real-time monitoring of environmental proxies relevant to algal event presence in the Highland Lakes chain, and will ultimately support water management, decision making, and risk communication.

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- The City of Austin Department of Watershed Protection
- The Lower Colorado River Authority

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